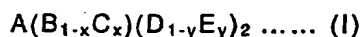


Claims

1. A quaternary or higher group IB-IIIA-VIA alloy having the
5 general formula (I):



wherein:

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A is a group IB element;

B is a group IIIA element;

C is a group IIIA element, which is different to B;

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D is a first group VIA element (hereinafter referred to as VIA₁);

E is a second group VIA element (hereinafter referred to as VIA₂); and

each of x and y independently are from 0 to 1, provided that both x and y are not zero at the same time;

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and the alloy being characterised by an x-ray diffraction pattern (XRD) having a main [112] peak at a 2θ angle (2θ₍₁₁₂₎) of from 26° to 28° for Cu radiation at 40kV, wherein a glancing incidence x ray diffraction pattern (GIXRD) for a glancing
25 angle of from 0.2° to 10° reflects an absolute shift in the 2θ₍₁₁₂₎ angle of less than 0.06°.

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2. The alloy of claim 1, wherein the alloy has a crystal structure comprising a lattice of unit cells, wherein all crystallographic planes of the unit cells show a variance in d-spacing of less than 0.01Å.

3. The alloy of claim 1, wherein the element concentration of elements A, B, C, D and E, as characterised by XPS depth profiling, is substantially uniform through the alloy.

5 4. The alloy of claim 1, wherein A is Cu, B is In, C is Ga, D is Se and E is S, the alloy having a formula (II):



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5. The alloy of claim 4, wherein x is from 0.25 to 0.3 and y is from 0.05 to 0.8

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6. The alloy of claim 4, wherein the x-ray diffraction pattern (XRD) has a main [112] peak at a 2θ angle ($2\theta_{(112)}$) of from 26.9° to 28° for Cu radiation at 40kV, taken at a d-spacing of from 3.3117\AA to 3.1840\AA .

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7. The alloy of claim 4, wherein the GIXRD for a glancing angle of from 0.2° to 10° reflects an absolute shift in the $2\theta_{(112)}$ angle of less than 0.01° .

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8. The alloy of claim 4, wherein the alloy has a crystal structure comprising a lattice of unit cells, wherein all crystallographic planes of the unit cells show a variance in d-spacing of less than 0.001\AA .

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9. The alloy of claim 6, wherein the main [112] peak is from a 2θ angle of from 27.0° to 27.5° .

10. The alloy of claim 6, wherein the main [112] peak is substantially symmetrical.

11. The alloy of claim 4, wherein the alloy has a band gap that can be shifted from 1 eV to 2.4 eV.
12. The alloy of claim 11, wherein the alloy has a band gap that
5 can be shifted from 1.1 eV to 1.5 eV.
13. The alloy of claim 4, wherein the S content, as expressed by the molar ratio of $\frac{S}{(S+Se)}$, is from 0.05 to 0.7.
- 10 14. The alloy of claim 1, wherein A is Cu, B is In, C is Ga, D is Se and $y = 0$, the alloy having the general formula (III)
- $$Cu(In_{1-x}Ga_x)Se_2 \dots\dots(III)$$
- 15 15. The alloy of claim 14, wherein x is from 0.25 and 0.3.
16. The alloy of claim 14, wherein the alloy has a crystal structure comprising a lattice of unit cells, wherein all crystallographic planes of the unit cells show a variance in d-spacing of less
20 than 0.006Å.
17. The alloy of claim 14, wherein the x-ray diffraction pattern (XRD) has a main [112] peak at a 2θ angle ($2\theta_{(112)}$) of from 26.80° to 27.0° for Cu radiation at 40kV, taken at a d-spacing
25 of from 3.3236Å to 3.2990Å.
18. The alloy of claim 14, wherein the GIXRD for a glancing angle of from 0.2° to 10° reflects an absolute shift in the $2\theta_{(112)}$ angle of less than 0.05°.
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19. The alloy of claim 17, wherein the main (112] peak lies from a 2θ angle of from 26.85° to 26.9°.
20. The alloy of claim 17, wherein the main (112] peak is substantially symmetrical.
21. The alloy of claim 14, wherein the alloy has a band gap which can be shifted from 1.1 eV to 1.2 eV.
22. The alloy of claim 21, wherein the alloy has a band gap which can be shifted from 1.15 eV to 1.18 eV.
23. The alloy of claim 14, wherein the Ga content, as expressed by the molar ratio of $\frac{Ga}{(Ga+In)}$ is from 0.25 to 0.3.
24. The alloy of claim 1, wherein A is Cu, B is In, D is Se, E is S and x = 0 and has the general formula (IV):
- $$CuIn(Se_{1-y}S_y)_2 \dots (IV)$$
25. The alloy of claim 24, wherein y is from 0.1 and 0.5.
26. The alloy of claim 24, wherein the alloy has a crystal structure comprising a lattice of unit cells, wherein all crystallographic planes of the unit cells show a variance in d-spacing of less than 0.007Å.
27. The alloy of claim 24, wherein the x-ray diffraction pattern (XRD) has a main (112] peak at a 2θ angle (2θ₍₁₁₂₎) of from 26.80° to 27.3° for Cu radiation at 40kV, taken at a d-spacing of from 3.3236Å to 3.2640Å.

28. The alloy of claim 24, wherein the GIXRD for a glancing angle of from 0.2° to 10° reflects an absolute shift in the $2\theta_{(112)}$ angle of less than 0.06°.
- 5 29. The alloy of claim 27, wherein the main (112) peak lies from a 2θ angle of from 27.0° to 27.2°.
30. The alloy of claim 24, wherein the alloy has a band gap which can be shifted from 1.05 eV to 1.23 eV.
- 10 31. The alloy of claim 30, wherein the alloy has a band gap which can be shifted from 1.15 eV to 1.20 eV.
32. The alloy of claim 24, wherein the S content, as expressed by
15 the ratio of $\frac{S}{(S+Se)}$ lies from 0.1 and 0.5.
33. A semiconductor film comprising a film of an alloy of claim 1.
34. The semiconductor film of claim 33, wherein the alloy of claim
20 1 is deposited onto a substrate which serves as a support for the alloy.
35. The semiconductor film according to claim 33, wherein the alloy is in the form of a film having a thickness of 1.5 to 2.0
25 μm .
36. A photovoltaic cell including a semiconductor film of an alloy of claim 1.
- 30 37. The photovoltaic cell according to claim 36, wherein the photovoltaic cell has a conversion efficiency of from 8 to 15%.